U.S. DEPARTMENT OF ENERGY

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# Committee Closeout Report on the CD-1 Review for the

# Muon g-2 Project

## Fermi National Accelerator Laboratory

**September 18, 2013**

**Kurt W. Fisher**
**Review Committee Chair**
**Office of Science, U.S. Department of Energy**
http://www.science.doe.gov/opa/

# Review Committee

**Kurt Fisher, DOE/SC, Chairperson**

**SC1**
**Beamline**

* Rod Gerig, ANL

**SC2**
**Storage Ring**

* Marc Ross, SLAC

**SC3**
**Detectors**

* Bill Wisniewski, SLAC

**SC4**
**Engineering**

* Ken Fouts, SLAC

**SC5**
**Cost and Schedule**

* Ethan Merrill, DOE/SC
  Frank Gines, DOE/ASO

**SC6**
**Project Management**

* Dan Green, Retired, FNAL
  Jeff Sims, ANL

**Observers**

Jim Siegrist, DOE/SC
Mike Procario, DOE/SC
Alan Stone, DOE/SC
Ted Lavine, DOE/SC
Tim Bolton, DOE/SC
John Kogut, DOE/SC
Paul Philp, DOE/FSO
Pepin Carolan, DOE/FSO
Alan Harris, DOE/SC
Mark Bollinger, DOE/FSO
Michael Weis, DOE/FSO
Robin Noyes, DOE/APM

**LEGEND**

SC Subcommittee
* Chairperson

**Count: 9 (excluding observers)**

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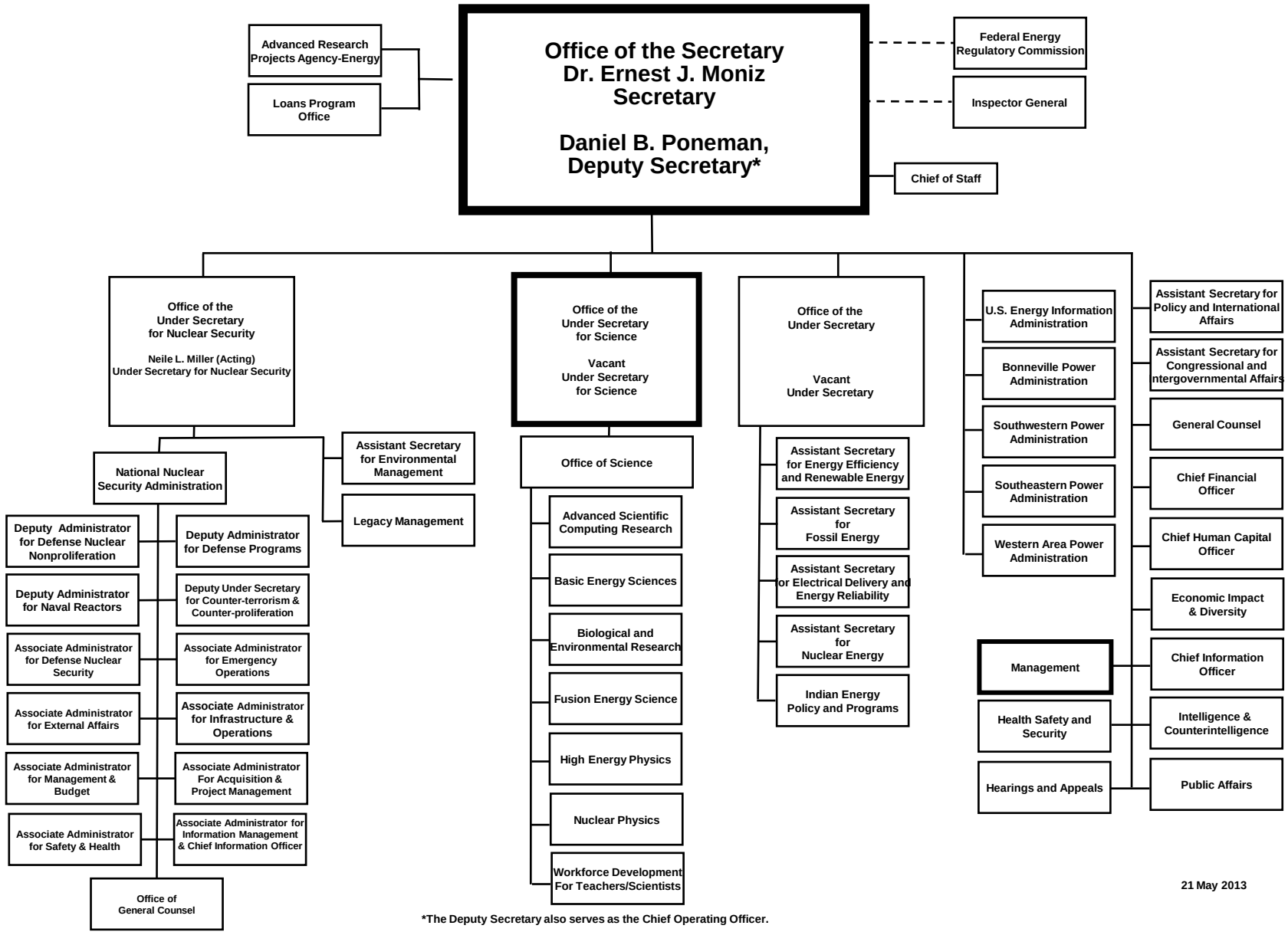


21 May 2013

*The Deputy Secretary also serves as the Chief Operating Officer.

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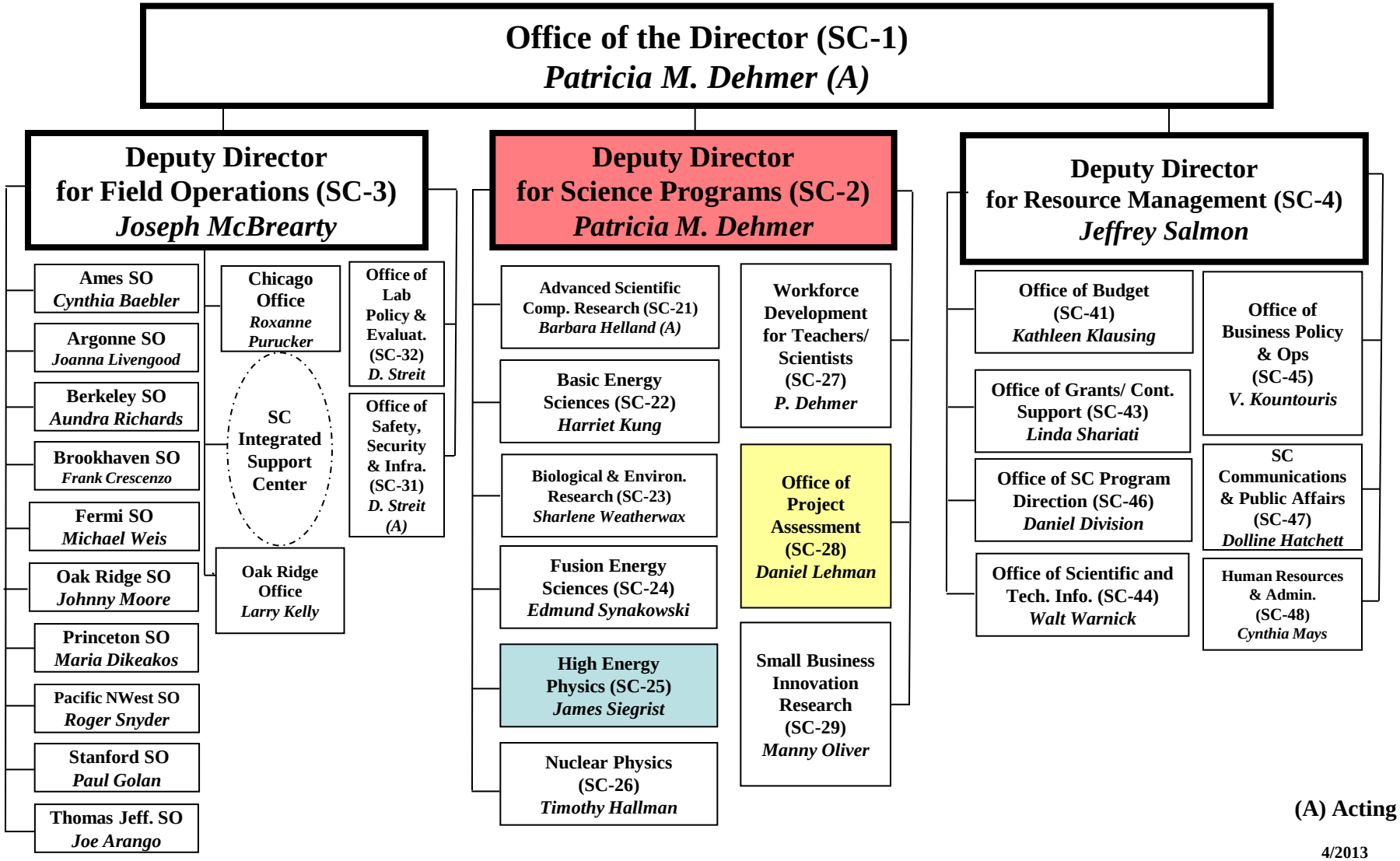


(A) Acting

4/2013

# Charge Questions



1. Does the conceptual design satisfy the performance requirements?

2. Do the conceptual design report and supporting documentation appropriately support the stated cost range and project duration?

3. Does the proposed project team have adequate management experience, design skills, and Laboratory support to produce a credible technical, cost and schedule baseline?

4. Are ES&H aspects being properly addressed and are future plans sufficient given the project's current stage of development?

5. Is the documentation required by DOE, satisfying Order 413.3B, ready for approval of CD-1?

# Expectations

- **Forward your sections for each review report (in MSWord format) to Casey Clark, casey.clark@science.doe.gov,**

  by September 23, 8:00 a.m. (EDT).

1. Does the conceptual design satisfy the performance requirements? Yes, the CDR is well developed and supports performance requirements.

3. Does the proposed project team have appropriate management experience, design skills, and Laboratory support to produce a credible technical, cost and schedule baseline? The team has considerable and appropriate experience in designing and implementing accelerator improvement projects, and continues to gain experience and training in DOE project management skills. The cost estimates are credible; the schedule reflects the realities of recent changes in funding guidance, and continues to be worked by the team.

5. Is the documentation required by DOE, satisfying Order 413.3B, ready for approval of CD-1? Yes

## Findings

- This scope of work is largely accelerator physics design work, and supporting magnets, power supplies, controls and instrumentation. The target station is also included in this scope of work.
  - 165 magnets will be supplied: 152 are repurposed without refurbishing, one will be refurbished and 12 will be fabricated, largely from existing designs
  - 170 power supplies will be procured, 44 will be reused. Of the new power supplies, two are large pulsed power supplies for the Lithium Lens, and the pulsed magnet, and many use switching mode technology.
  - The target station reuses as much of the pbar hardware as possible, new equipment is driven by the more demanding repetition rate of g-2.

**Comments**

- Fermilab has made significant progress in describing the dependencies between the g-2 project, the mu2e project and the seven supporting AIP and GPP projects.
- Diagnostics are well thought out and adequate for commissioning and operation.
- Risk analysis mature for this stage of project.
- Effort leveling remains a concern throughout this scope of work, as well as the g-2 project and muon campus activities. This is a Fermilab wide issue which needs constant attention to efficiently move people off and back on to various project funding sources.
- A number of value engineering measures have been taken to reduce costs and accelerate the schedule. The team continues to investigate other opportunities.

**Comments**

- Ensure a method of physics design verification, using an appropriate combination of independent evaluation, detailed technical reviews, etc.
- Although safety issues are being considered at this phase of the project, ensure that there is communication with those who will prepare the Safety Assessment Document (SAD) and ultimately carry out the Accelerator Readiness Reviews (ARR).
- Drill downs in this area into the Basis of Estimates (BOEs) revealed credible estimates. Two categories were evaluated; one focusing on procurements, and another looking at effort intensive activities.
- Due to funding issues, a number of accelerator activities have been pushed into the final year, the committee is concerned that this may lead to schedule issues, and every effort should be made to bring appropriate FY17 work scope forward.

## Recommendation

1. Proceed to CD-1 approval.

1. Does the conceptual design satisfy the performance requirements?
   - YES

3. Does the proposed project team have appropriate management experience, design skills, and Laboratory support to produce a credible technical, cost and schedule baseline?
   - **YES, n.b. →**
   - **The project team has excellent technical base – (experience BNL E821). A training program is place to augment project management team member management experience.**

5. Is the documentation required by DOE, satisfying Order 413.3B, ready for approval of CD-1?
   - YES

- **Findings 476.03: Storage Ring**
  - The success of g-2 at Fermilab (E989) requires greatly increased statistics and greatly improved control of systematic errors (compared to BNL E821).
  - **Calibration precision and stability are key to reducing systematic error.**
  - The Storage Ring team brings experience from BNL E821 and while retaining and re-applying much of their technique they also intend to develop new procedures and apply ‘lessons-learned’.
  - **Pole alignment, magnetic field shimming and testing are critically important to achieve desired improvements in systematic errors.**
  - **Beneficial occupancy of MC-1 is foreseen in February 2014. Intensive activity is expected to take place in the period February 2014 to February 2015.**

- **Findings 476.03.02: Magnet**
  - **An alignment task force was established in June 2013 with charge to:**
    - **Discuss the requirements and technical issues to develop a coherent alignment strategy**
    - **Write a central summary document for CD-1 review since alignment spans several BoE's (n.b. mostly 476.03.02)**
    - **Step-by-step details to refine the metrology labor efforts**
  - **The project alignment work is substantial, amounting to about 1/3 of the metrology group's capacity for the better part of a year.**
- **Comments**
  - **Metrology resources are a precious commodity and care should be taken to negotiate their deployment properly so as to minimize conflict with other lab priorities.**
- **Recommendations**
  - **Prepare a plan (resource-loaded schedule) for the use of metrology and related skilled labor and present it at the next review.**

- **Findings 476.03.03: Inflector**
  - **Inflector magnet development may help muon beam capture in the storage ring. Using technology based on recently improved superconductor wire, Rutherford Appleton Lab (UK-STFC) is considering a new inflector as an in-kind contribution to the project.**
  - **The inflector geometry is extremely constrained. It was reported that it would be impossible to make adjustments to the existing geometry.**
- **Comments**
  - **A substantial performance increase may be possible and the project should be encouraged to solicit and make effective use of this offer of help.**
  - **This contribution does not come without cost. On-project integration resources, possibly significant, would be required.**
- **Recommendations**
  - **None**

- **Findings 476.03.05: Kicker**
  - **The BNL E821 kicker field was too weak and did not meet specification. A new kicker system under development by Cornell collaborators has a modified stripline shape that should increase the kick significantly with the same voltage and current. It should be able to meet performance specifications.**
- **Comments**
  - **The kicker is a very high voltage, high current device deployed in a facility full of high sensitivity, precisely calibrated equipment. Kicker operation may seriously reduce the performance of instrumentation electronics.**
  - **Even though the kicker pulse repetition frequency is no more than 120 Hz, electrical disturbances caused by the pulse may last a long time.**
  - **Care must be taken to match the pulser properly to the stripline.**
  - **Care must be taken to minimize coupling between the kicker and surrounding electronics. In-situ testing is required and must be included in the plan.**
- **Recommendations**
  - **None**

- **Findings 476.03 – Beam Diagnostics**
  - **The project is considering ways to reduce 'CBO' (coherent betatron oscillation) including active feedback. CBO is a possible source of significant error because the oscillation frequency lies close to a harmonic of the frequency of interest.**
- **Comments**
  - **CBO should be reduced using whatever means possible. Non-destructive beam diagnostic techniques should be developed and used.**
- **Recommendations**
  - **None**

- **Findings**
  - **The Storage Ring 476.03 schedule shows effort turn-down in FY15 and 16 with little or no work in FY17.**
- **Comments**
  - **Beam-on is not scheduled to occur until FY2018.**
  - **The Storage Ring team should remain intact to participate in g-2 E989 beam commissioning.**
  - **Resources (staff and funding) are required for ongoing testing and to maintain the ring in good working condition. These are not listed as part of the project but are assumed to be 'operations'.**
  - **Consumables (e.g. cryogens) and spares will be required in addition to key staff**
- **Recommendations**
  - **Prepare a plan for transition to storage ring operations including staffing and funding requirements and present it at the next review.**

1. Does the conceptual design satisfy the performance requirements?

   *Yes, the conceptual design satisfies the performance requirements.*

3. Does the proposed project team have appropriate management experience, design skills, and Laboratory support to produce a credible technical, cost and schedule baseline?

   *Yes. The Detector team has significant expertise from the prior g-2 experiment, as well as other similar experiments. They have the knowledge, experience and design skills to produce a credible technical, cost and schedule baseline.*

5. Is the documentation required by DOE, satisfying Order 413.3B, ready for approval of CD-1?

   *Yes*

- **Findings**
  - The Detector team gave presentations on the L3 systems: Calorimeter, Tracker, Backend Electronics, Fast DAQ , Auxiliary detectors, and Slow Controls.
  - Systems descriptions and performance expectations and current design status were shown, along with collaborating institution construction responsibilities.
  - Costs were presented. Bases of Estimate, including contingencies, were examined in detail for Calorimeter Calibration, Backend Electronics, and Tracker. Funding sources (DOE Project, DOE Early Career Award, and NSF) were identified for each WBS L4 element.
  - P6/Cobra schedules, and the process for generating the schedule, were presented. Milestones to track detector systems progress have been established and appear in the master schedule.
  - ES&H considerations were presented by each of the L3 managers.

- **Comments**
  - The Detector design, costing, and schedule are at the level of or exceed the level expected for CD-1. The management team is to be commended for this.
  - Calorimeter prototyping is advanced. Effort has focused on development of the photo-sensors, the SiPMs. This is a technological departure from past *g-2* experiments, but is taking good advantage of new technology. The R&D effort is close to completion.
  - Calorimeter mechanical engineering is at a conceptual, rather than detailed level.
  - The active material for Calorimeter, $PbF_2$, has been selected and a handful of prototypes characterized. Crystals from a single vendor have been the focus of effort. This vendor has a history of reliability and favorable pricing, and the number of crystals to be produced should not tax the vendor's production abilities. However, the team should seek out additional vendors for availability and pricing, as a backup solution. Before going out for final crystal production and SiPM procurement, the team should hold a expert's review of the design solution.
  - NSF has funded the bulk of the Calorimeter effort. This is backstopped by University of Washington. Only the calibration system is on the DOE Project. Italian collaborators have provided much of the R&D effort on the calibration system, and INFN may take this on as an in-kind contribution.

- **Comments**
  - The design of the backend electronics is conservative and provides headroom for expanded capability. This L3 system is in good shape. The ADC, a major cost item of the Wave-Form Digitizer, will be provided gratis by Texas Instruments. The funding agency for this work is NSF. If the funding should prove inadequate, it will be backstopped by Cornell University.
  - The Tracker uses mylar straw tubes, a mature technology. Mechanical engineering for this system relies on student effort at NIU, backed by review of designs by experienced Fermilab engineers. This seems to be working, and is an innovative way to contain design costs. There is risk here, if Fermilab engineering is needed, that it may not be immediately available. The production will piggy-back off the larger Mu2e straw production. Funding for the Tracker effort comes from the L3 manager's Early Career Award, and should be adequate.
  - The Fast Data Acquisition system cover control, readout, monitoring and storage of the data. The system uses the MIDAS framework. This system is not at this time supported by Fermilab. However, many members of the collaboration have extensive experience with this system, which also provides a solid basis for support of Slow Controls. The Committee feels that the team has made a reasonable choice here.

- **Comments**
  - Components of the auxiliary detector set, as well as detectors from the last generation of *g-2,* are at BNL. The team should make and execute plans to transfer these items to Fermilab as soon as possible.
  - The cost estimates for the systems appear to be reasonable. The Committee drilled down in several BoEs (Calorimeter Calibration, Backend Electronics, and Tracker). The BoE technology, backed up by detailed documents, provides adequate detail to justify the costs. The managers are familiar with, and adept at, using these estimate. The team has a good sense of the change control process, and uses it.
  - The schedule is based on inputs from the managers. With full funding in hand for the NSF MRI, funding effects on schedule are less onerous.
  - The schedule contains adequate milestones for reviews. The team should develop a 'review' strategy for incorporating external expert reviewers for critical reviews.
  - The test beam activities in FY14 at SLAC are critical to Detectors.
  - The management team should give consideration to backup plans. R&D has gone well. Procurement and construction may also go well, but there are likely to be glitches, and backup plans will help to deal with these.

- **Recommendations**

1. Proceed to CD-1 approval.

1. Does the conceptual design satisfy the performance requirements?

   Yes. The project presented a level of preparation consistent with conceptual design .

3. Does the proposed project team have appropriate management experience, design skills, and Laboratory support to produce a credible technical, cost and schedule baseline?

   Yes. The project is well organized and has identified resources with the appropriate disciplines and level of experience to support the scope of work.

5. Is the documentation required by DOE, satisfying Order 413.3B, ready for approval of CD-1?

   Yes. The current level of documentation to support the technical effort is at the appropriate level for a CD-1 approval.

- **Findings**

1. The Final Design has been delayed in the project schedule to fit the funding profile, leaving a one year gap between Preliminary and Final Design tasks.
2. The mechanical and electrical engineering effort is clearly identified and detailed in the project BoE's.
3. Re-use/refurbishment of E821 hardware from Brookhaven National Laboratory represents a large fraction of the total engineering effort for the project.

- **Comments**

1. Engineering tasks are well defined for the refurbishment and repurposing of the E821 hardware from BNL.
2. The mechanical and electrical engineering staffing levels and expertise are appropriate for the tasks that are identified in the current project schedule.

- **Comments (cont'd)**

3. The Storage Ring plan includes many instances of early risk reduction by testing of existing subcomponents prior to full installation. The project is encouraged to look for additional risk reduction opportunities, should there be unanticipated delays in other AIP's that impact the start of installation.
4. The estimate uncertainty for many of the engineering related tasks remains at the expert opinion (60%) level, which may be too conservative for tasks with a minimal amount of new engineering effort i.e. new design. Reducing this uncertainty between CD-1 and CD-2 may present opportunities for additional scope or early completion of tasks that have been delayed due to the proposed funding profile.

- **Recommendations**

1. Develop a definitive plan for delivery of all of the remaining hardware from BNL prior to CD-2. This may provide additional opportunity for early risk retirement that should be identified in the project schedule at CD-2.

2. Do the conceptual design report and documentation appropriately support the stated cost range and project duration? **YES**

3. Does the proposed project team have appropriate management experience, design skills, and Laboratory support to produce a credible technical, cost and schedule baseline? **YES**

5. Is the documentation required by DOE, satisfying Order 413.3B, ready for approval of CD-1? **YES**

## Findings

- The project has prepared a preliminary resource-loaded schedule reflecting OHEP funding guidance. **Financial impact to the schedule results in $2M in Final Design work delayed to FY2015 and $7M in accelerator work delayed to FY2017.**
- The preliminary project schedule includes contributed (NSF/ECA) activities and identifies critical milestones related to Muon Campus activities.
- The project schedule includes 12 months of schedule contingency to CD-4 (~25%) as well as 6 months float to L1 milestones and 3 months float to L2 milestones.
- The preliminary DOE total project cost is $47.9M including $10M estimate uncertainty contingency and $2.4M risk-based contingency. Total project contingency is approximately $12.4M (~41% of to-go costs). The proposed CD-1 cost range is $43M-$50.1M.
- The DOE Base Cost is $35.574M/Early Career Award is $980K/ NSF is $3.085M. The total base program is $39.638M.
- The base estimate is 45% materials and services and 55% labor.
- The estimating methodology documents the project rules for estimating and applying contingency.
- The project includes minimal scope contingency.

## Comments

- The cost contingency is time-phased in the project schedule and appears reasonable at 41% of to-go costs.
- The overall cost estimate is detailed and mature for this stage of the project and the process used to develop the estimates is documented and credible. The project is using estimating assumptions which appear to result is a conservative estimation of the total project cost. The project should continue to further develop and refined the estimates for CD-2.
- During the estimate traces, the technical leads demonstrated detailed knowledge and appropriate ownership of the cost estimates.
- The schedule contingency appears reasonable for this stage of the project.
- The preliminary resource loaded schedule is well-developed and detailed but appears sub-optimized due to funding constraints. A technically-driven schedule is preferred; OHEP and the project should continue to evaluate funding options/alternatives to eliminate these constraints.

## Recommendations

- Continue to refine the cost estimates and project schedule prior to CD-2
- Proceed to CD-1

# Muon g-2 Project Status

Merrill, DOE/SC; Gines, DOE/ASO



| Muon g-2 PROJECT STATUS as of August 2013 | | |
|---|---|---|
| Project Type | MIE | |
| CD-1 | Planned: 1st Q FY14 | Actual: |
| CD-2/3a | Planned: 3rd Q FY14 | Actual: |
| CD-3b | Planned: 2nd Q FY15 | Actual: |
| CD-4 | Planned: 4th Q FY18 | Actual: |
| TPC Percent Complete (based on point estimate) | Planned: _____% | Actual: _____11.5% |
| TPC Cost to Date | $5.5M | |
| TPC Committed to Date | | |
| TPC range | $43M-$50.1M | |
| TPC point estimate | $47.9M | |
| Contingency Cost (w/Mgmt Reserve) | $12.37 | _____41.2% to go |
| Contingency Schedule on CD-4 | _____12_months | _____25% |
| CPI Cumulative | | |
| SPI Cumulative | | |

# 4. Project Management

**D. Green, Retired FNAL, .J. Simms, ANL / SC6**

Does the proposed project team have appropriate management experience, design skills, and Laboratory support to produce a credible technical, cost and schedule baseline?

Yes – the Project Management team is strong and experienced.

Are ES&H aspects being properly addressed and are future plans sufficient given the project's current stage of development?

Yes – the position has been filled.

Is the documentation required by DOE, satisfying Order 413.3B, ready for approval of CD-1?

Yes – a full set of the required CD-1 documents was posted and presented.

## Findings

- The project management team presented the WBS and the resource loaded schedule (RLS).
- The documentation was complete and of a sufficient granularity at this stage of the g-2 project
- The schedule, as shown, was contingent on a draft funding profile.
- The cost estimate had a full contingency analysis applied with full granularity.
- A critical path was shown in a technically limited scenario.
- The Project has rapidly integrated the DoE, NSF, and other resource types into a coherent, unitary effort.

## Comments

- The uncosted resources were identified and amounted to 13 M$. This is a potential exposure but it also indicates the level of commitment of the g-2 Collaboration.
- Forward funding should be explored within the Collaboration
- There is currently no scope contingency identified. Scope contingency (potential reductions and enhancements) should be identified prior to CD-2.
- It is difficult to optimize the schedule with the guidance of the DoE funding profile.
- The interface Milestones with the Accelerator Division(AD) is a useful and necessary tool, especially as AD is 60% of the Project.
- The Project may consider interior dependencies across L2 or L3 and add interface Milestones.
- The Project may consider annual statements of work with all collaborating institutes in order to secure the needed resources in a timely fashion.

**Comments**

- Drilldown exercises were performed successfully. The team "owns" the BoE and WBS.
- The boundary between Project, installation and commissioning tasks should be well defined and agreed to prior to CD-2.
- The project has begun to track actuals. This is very useful to follow cost experience. To date cost experience has been good.
- If future cost experience is good, contingency may be earned and items may be added from the Risk Registry.
- Prior to CD-2 the project should resource level the funding constrained fiscal years to identify the critical path activities.
- The project should reconsider the gap in design work or identify it as a project risk.
- The tracking granularity appears to be about 300 k$. That may be a bit too coarse to follw the cost experience on a given WBS item.
- Labor experience for refurbishment and repair should be closely monitored as the cost implications are large.
- Consider holding a Procurement Readiness Review and an Installation readiness Review for large cost items.

# 4. Project Management

D. Green, Retired FNAL, J. Simms, ANL / SC6

1. Consider tracking actuals at a lower WBS level prior to CD-2
2. Prior to CD-2, work with the agencies to define a more effective schedule, without design gaps and without AD work being back loaded to FY17.
3. Using FY14 spending experience review future project cost estimates to ensure appropriate base and contingency estimating prior to CD-2.
4. Finalize the required DoE documents for CD-1.
5. Proceed to CD-1